Norsk Regnesentral
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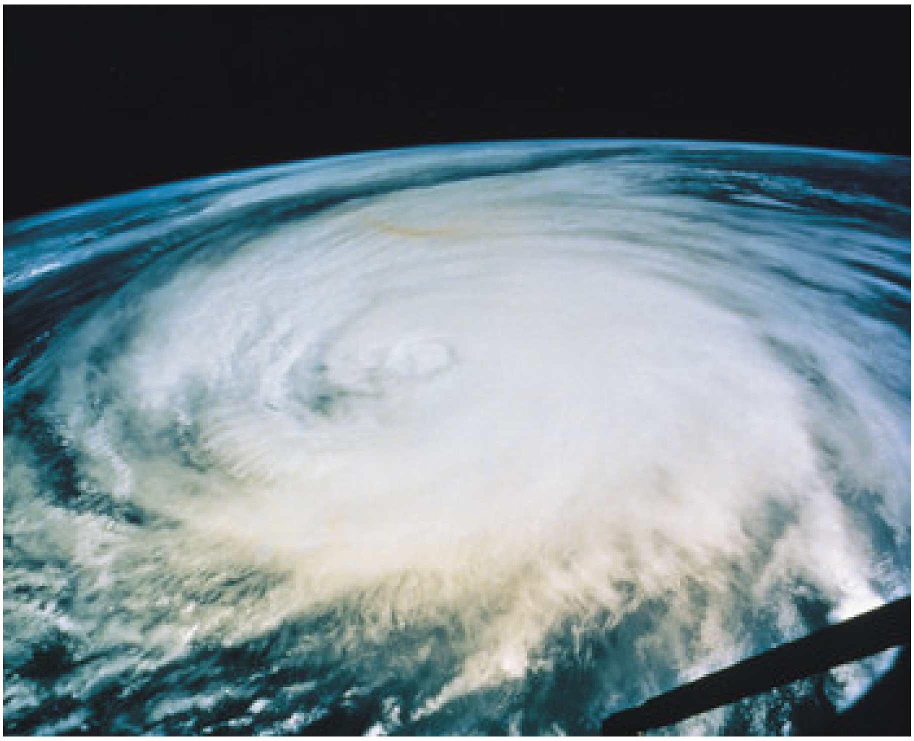
Note

Supplemental material to: Evaluation of a dynamic downscaling of Norwegian precipitation



Note no SAMBA/50/10

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Date October 2010

Norwegian Computing Center

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Title	**Supplemental material to: Evaluation of a dynamic downscaling of Norwegian precipitation**

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Abstract

This paper is a supplement to the article "Evaluation of a dynamic downscaling of Norwegian precipitation". We have studied several other measures that are not included in the article. The remaining pictures are shown here. In addition to the spatial map of p-values, we also show the histogram of p-values for two selected measures.

Keywords	downscaling, precipitation, ERA-40 reanalysis, Kolmogorov Smirnov, GPD, Extreme Value Theory
Target group	
Availability	Open
Project	Insuring Future Climate Change
Project number	220432
Research field	Bank, Finance, Insurance and Power Market
Number of pages	28

Contents

1 Introduction

We have studied several other measures that are not included in the article. We will show the remaining pictures in this supplemental material. In addition to the spatial map of p-values, we also show the histogram of p-values for two selected measures. If the null hypothesis is true, this histogram should look like draws from a uniform distribution.

2 Methods

Several different measures were employed to compare downscaled ERA-40 re-analysis model data (dERA40) and observed precipitation. As mentioned in the article we have used a threshold of 0.5 mm/day to define a wet day. Most of the measures are therefore conditioned on wet days, i.e dry days are left out. Exceptions are ”Maximum 5-day sum of precipitation” and ”Maximum number of consecutive dry days”, where still the threshold of 0.5 mm/day is used to define a wet or dry day, but dry days are not left out.

The measures that are considered here include equality of the means, standard deviation, different quantiles[1], maximum 5-day precipitation and maximum number of consecutive dry days. In addition two comparative methods to the Kolmogorov Smirnov test are shown in Appendix A.

All tests are done seasonally and based on the 777 grid cells that cover Norway. We then have 4 x 777 (=3108) tests for each measure. If all null hypothesis are true, we would expect about 155 spurious significances.

2.1 Mean intensity

The equality of the mean intensity of the two data sets is tested using a t-test over the whole period of 40 years. A t-test can be used according to the central limit theorem since we have a lot of data (40 years). Because we condition on wet days, dry days are left out.

2.2 Standard deviation

The equality of the standard deviation is tested by permutation testing (e.g. Good (2005)). This is done by resampling the two data sets 1000 times. The resampling is done day by day, i.e. with 50% probability we exchange the ERA40 data and the observation at a given day. The standard deviation is then calculated for both the resampled ERA40 data and the resampled observations. The null-hypothesis is that the ERA40 data and observations have the same standard deviation. The p-value is calculated by finding the order of the difference of the standard deviation among the sorted 1000 differences of standard deviations calculated from the resampled data sets (and multiplied with 2 to get a p-value for a two-side-test).

1. 0.10-quantile, 0.25-quantile, median, 0.75-quantile and 0.90-quantile

2.3 Quantiles

Fisher exact test (e.g. Bickel and Doksum (1977)) is used for testing the equality of a given quantile as described in the article.

2.4 Maximum 5-day sum of precipitation

The equality of the maximum 5-day sum of precipitation (i.e. maximum sum of precipitation in a consecutive period of five days) is tested by permutation testing. This is done by resampling of the two data sets 1000 times. To account for autocorrelation blocks are used to exchange the data instead of one day at a time. A block length of one season is chosen, to account for the autocorrelation within the whole block. The p-value is found by similar calculation as described in section 2.2.

2.5 Maximum number of consecutive dry days

The equality of the maximum number of consecutive dry days is tested by permutation testing. This is done by resampling of the two data sets 1000 times. The resampling is done by blocks with length of one season, instead of exchanging one day at a time. The p-value is found by similar calculation as described in section 2.2.

2.6 Bonferroni adjustment

A Bonferroni correction is performed to correct for multiple testing (e.g. Bickel and Doksum (1977)). The Bonferroni correction is derived by observing Boole's inequality. The probability that at least one of n tests comes out significant is:

$$\alpha \leq n \cdot \beta \tag{1}$$

The significance level for each of the tests is now set to $\beta = \alpha/n$. This result does not require the tests to be independent.

2.7 Linear adjustment

dERA40 has been transformed by using a simple linear regression. Since dERA40 partly has lost the day to day correspondence when downscaling from the ERA-40 re-analysis data, a regression is based on the mean value per season of the 40 years as shown in (2).

$$\mu_{dERA40^{season,year}_{transformed}} = a + b * \mu_{dERA40^{season,year}_{original}} \tag{2}$$

The transformation is performed on each grid cell and each season independently. For a given season and grid cell there are then 40 mean values for each data set. The mean value is taken over all days (about 90 days) in a season each year. dERA40 is then forced to have the same mean value as the observations. When transforming dERA40, all days are included, i.e. dry days are not removed.

3 Results

For all the tests a significance level, α, of 5% is used.

3.1 Mean intensity

There are some non-rejections (yellow grid cells) of that the means are the same in Figure 1. As for the Kolmogorv Smirnov test, these non-rejections are more or less random, i.e. there are no specific pattern.

Mainly there are rejections, and this is shown as red and blue grid cells. There are more blue grid cells than red; this means that dERA40 has less mean intensity than the observations in more grid cells than the opposite. There are some indications of less mean intensity of dERA40 than the observations at the west coast (above Hordaland) and in the inner parts of Norway (there are darker blue grid cells here). In Finnmark there are some indications that dERA40 has greater mean intensity (red grid cells) than the observations in all seasons, except in summer.

There are not any great differences in the different seasons, except less red grid cells in summer as mentioned.

3.2 Standard deviation

The picture of the differences in standard deviation in Figure 2 is almost the same as for the mean intensity, both in the portion of non-rejections and rejections and in the difference in seasons.

3.3 Quantiles

For the 0.10-quantile (Figure 7) there are some more rejections than for the 0.05-quantile (Figure 2 in the article), but still there are mainly non-rejections. Among the west coast in winter there are indications that the 0.10-quantile of ERA40 is less than for the observations, since there are some blue grid cells here.

For the 0.25-quantile in Figure 8 there are less non-rejections than for 0.05- and 0.10-quantile. There are mostly light blue grid cells, i.e. that in this areas we have rejected that the 0.25-quantile of ERA40 are the same as for the observations, and 0.25-quantile of ERA40 is less than for the observations. Specially in winter there are greater indication that the 0.25-quantile of ERA40 is less than the observations among the west coast, since there are some darker blue grid cells here. This difference is greater for the 0.25-quantile than for the 0.10-quantile.

For the median in Figure 9 we still see that ERA40 is less than for the observations among the west coast for all seasons, but there are some greater indication in winter. For the inner parts of Norway and the part of Finnmark that is next to Finland there is indication that the median of ERA40 is greater than for the observations since there are red grid cells here.

The pictures of the 0.75-, 0.90- and 0.95-quantiles in Figures 10, 11 and Figure 3 in the article are more or less the same. As described in the article there are some non-rejections in Finnmark and in random parts of Norway, but there are mainly blue grid cells. A blue grid cell indicates that the distributions differ, and that the 0.95-quantile of dERA40 is less than the 0.95-quantile of the observations. This tells us that dERA40 have problems modeling high precipitation. There are some few red grid cells in Finnmark and in inner parts of Norway, which indicates that the distributions differ and that the 0.95-quantile of dERA40 is higher than the 0.95-quantile of the observations.

Bonferroni correction of test of the 0.05-quantile and the 0.95-quantile are shown in figures 5 and 6. There are some more non-rejections with Bonferroni correction, but the structures are the same as without Bonferroni correction (figures 2 and 3 in the article). This indicates that there are no problem in testing many tests at the same time. Bonferroni correction of the other measures show the same as those shown here, that the structures with Bonferroni correction are the same as without Bonferroni correction, and hence they are not shown.

Histograms of the p-values of the test of the 0.05-quantile and the 0.95-quantile are added here, and are shown in figures 3 and 4. The histograms of the p-values of the tests of the 0.05-quantile look like draws from a uniform distribution, while the histograms of the p-values of the tests of the 0.95-quantile show a peak around 0. The histograms show the same as the spatial figures of the p-values, that there are greater problems in the right tail of the distribution of dERA40 than in the left tail. Histograms of the other measures are also consistent with their spatial figures, and are not shown.

3.4 Maximum 5-day sum of precipitation (MAX5)

Figure 12 shows that there are a lot of non-rejections (yellow grid cells) for all seasons. There are some more non-rejections in summer.

In the inner parts of Norway, Nordland and Troms there are mainly blue grid cells, i.e. that MAX5 is less for dERA40 than for the observations. In Finnmark there are some indication of that MAX5 is greater for dERA40 than the observations in winter and spring.

The picture of MAX5 is a different picture than what we saw for the high quantiles (0.75-, 0.90- and 0.95-quantiles in section 3.3). The test of maximum 5-day sum of precipitation might give an impression of that dERA40 models the extremes well in some areas. We have to keep in mind how this test is made. It tests the maximum 5-day sum of precipitation of a season over all the 40 years.

The test of wet day frequency (in section 4.2.2 in the article) tells that dERA40 models less rainy days than we have observed in the history. It might be that the observations have more series of a high 5-day sum than dERA40. To check this, Table 1 shows the number (all grid cells) of 5-day series where the sum exceeds 200 mm/d. In winter, spring and autumn there are over double as many 5-days sum that exceeds 200 mm/day for the observations as for dERA40. This agrees with our assumption. The exception is summer, where there are not much of a difference in the number of 5-days sum exceeding 200 mm/day for dERA40 and the observations, but dERA40 has some more 5-day sum exceeding 200 mm/day than the observations. This agrees with the spatial picture in Figure 12, where there are some more non-rejections in summer than in the other seasons.

Table 1. The number (all grid cells) of 5-days series where the sum exceeds 200 mm/d.

	dERA40	observations
winter	4 288	10 550
spring	1 081	2 961
summer	855	702
autumn	4 195	9 563

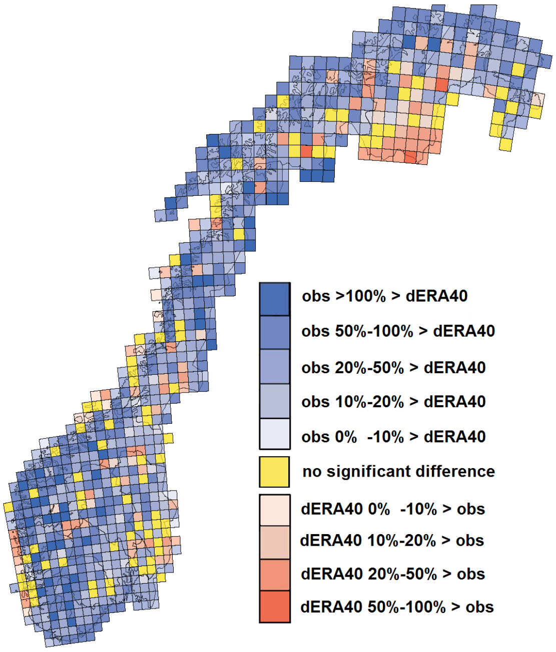
3.5 Maximum number of consecutive dry days (MAXDRY)

The picture of the maximum number of consecutive dry days in Figure 13 also shows a lot of non-rejections as the test of maximum 5-day precipitation in section 3.4. There are some more non-rejections in the summer than for the other seasons. In the inner parts of Norway and Finnmark (specially for spring) there are mainly blue grid cells, i.e. that MAXDRY is less for dERA40 than for the observations. Note that there are more blue grid cells than red, this means that dERA40 has shorter consecutive dry days than the observations. Since both dERA40 has less consecutive dry days than the observations and also less wet day frequency, this might be an indication of that dERA40 has less time dependence than the observations.

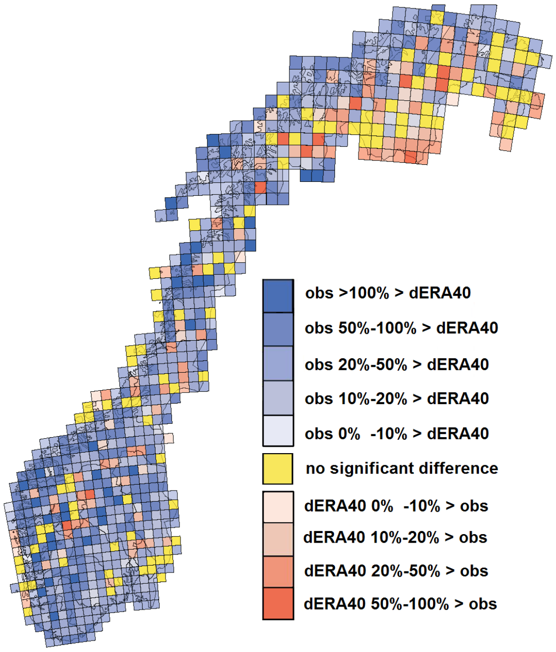
MAXDRY tests the maximum consecutive dry days for a season of 40 years. It might be that the observations have more series of long consecutive dry days than dERA40. To check this, Table 2 shows the number (all grid cells) of consecutive periods of dry days that exceed 15 days. In all seasons the observations have more periods of consecutive dry days that exceeds 15 days than dERA40. This is most obvious for winter and spring. This agrees with our assumption.

Table 2. The number (all grid cells) of consecutive periods of dry days that exceeds 15 days.

	dERA40	observations
winter	335	1 447
spring	248	2686
summer	445	775
autumn	134	379



(a) **Winter;**
max blue: OBS 279% > dERA40,
max red: dERA40 91% > OBS.



(b) **Spring;**
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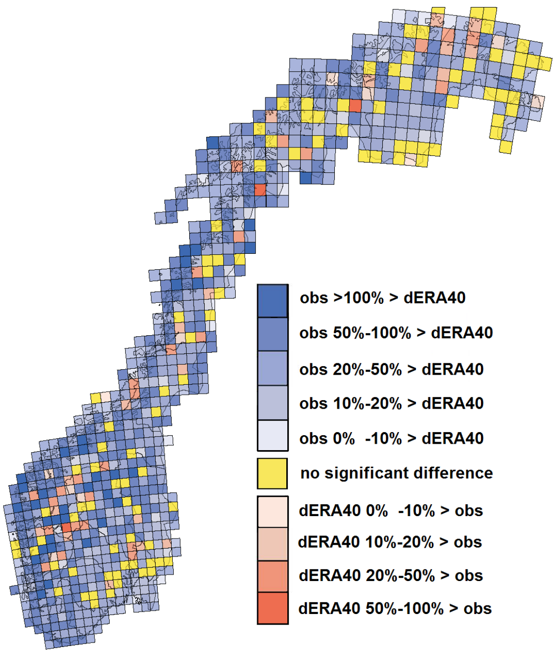
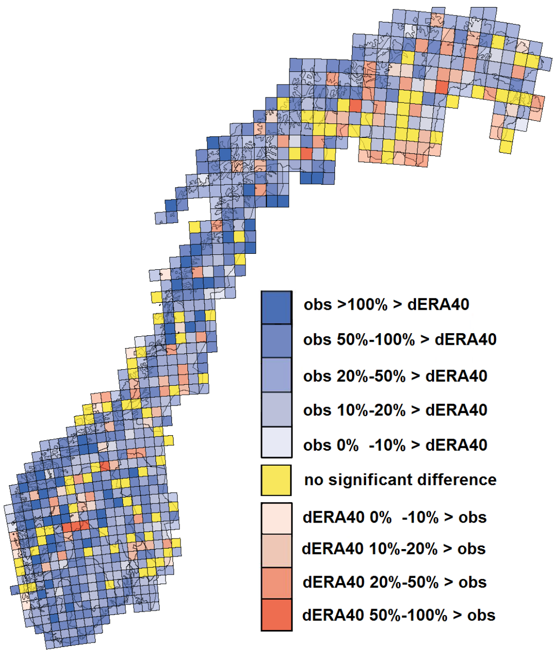
max red: dERA40 100% > OBS.

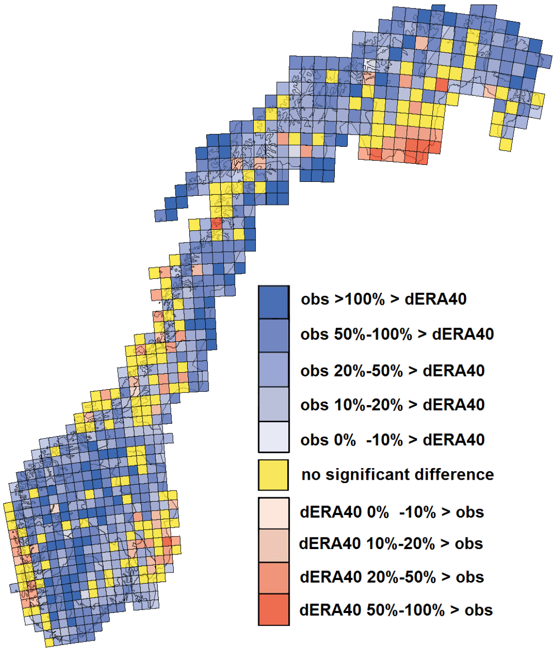


(c) **Summer;**
max blue: OBS 202% > dERA40,
max red: dERA40 89% > OBS.



(d) **Autumn;**
max blue: OBS 235% > dERA40,
max red: dERA40 86% > OBS.

Figure 1. Test of the difference of the mean intensity (conditioned on wet days), $\alpha = 0.05$. When the $p - value > \alpha$, we keep the hypothesis that $\mu_{ERA40} = \mu_{OBS}$, and this is shown by a yellow color of the grid cell. When $p - value \leq \alpha$ the color of a grid cell is either red or blue, dependent on the direction of the ratio of ERA40/OBS. The darker color of a grid cell, the greater or smaller value of the ratio of ERA40/OBS, as shown in the table. Blue color indicates that $\mu_{ERA40} < \mu_{OBS}$, significantly, and red color indicates that $\mu_{ERA40} > \mu_{OBS}$, significantly.



(a) **Winter;**
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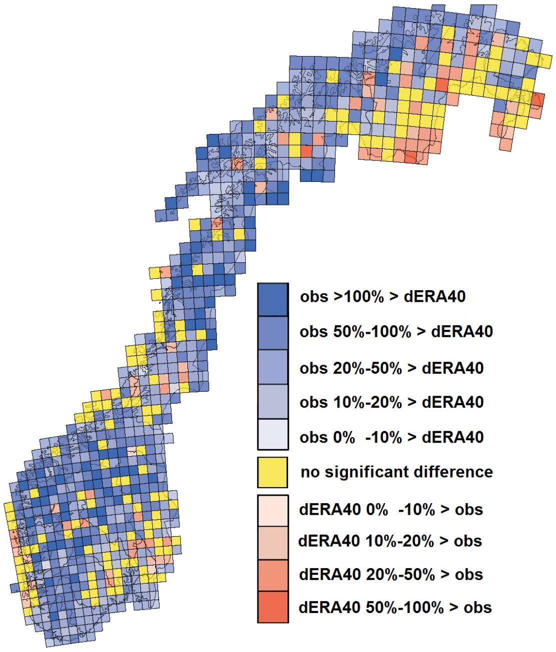
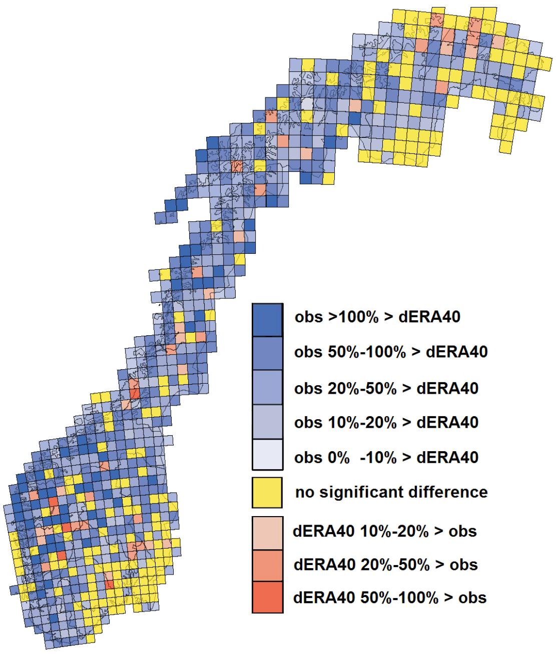
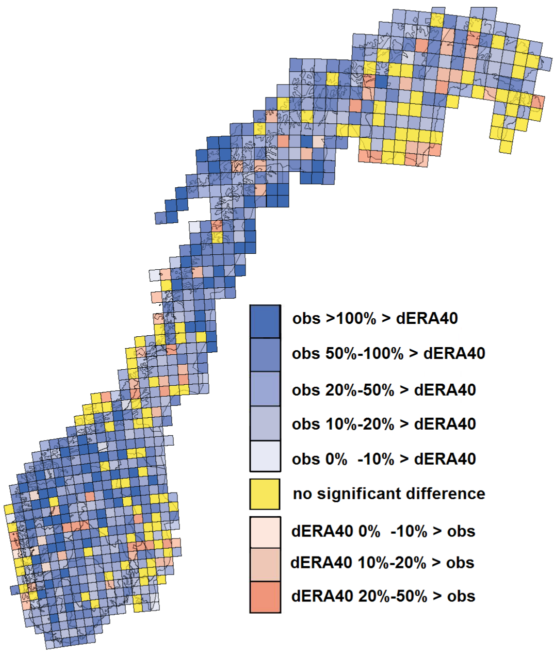
max red: dERA40 72% $>$ OBS.



(b) **Spring;**
max blue: OBS 282% $>$ dERA40,
max red: dERA40 79% $>$ OBS.

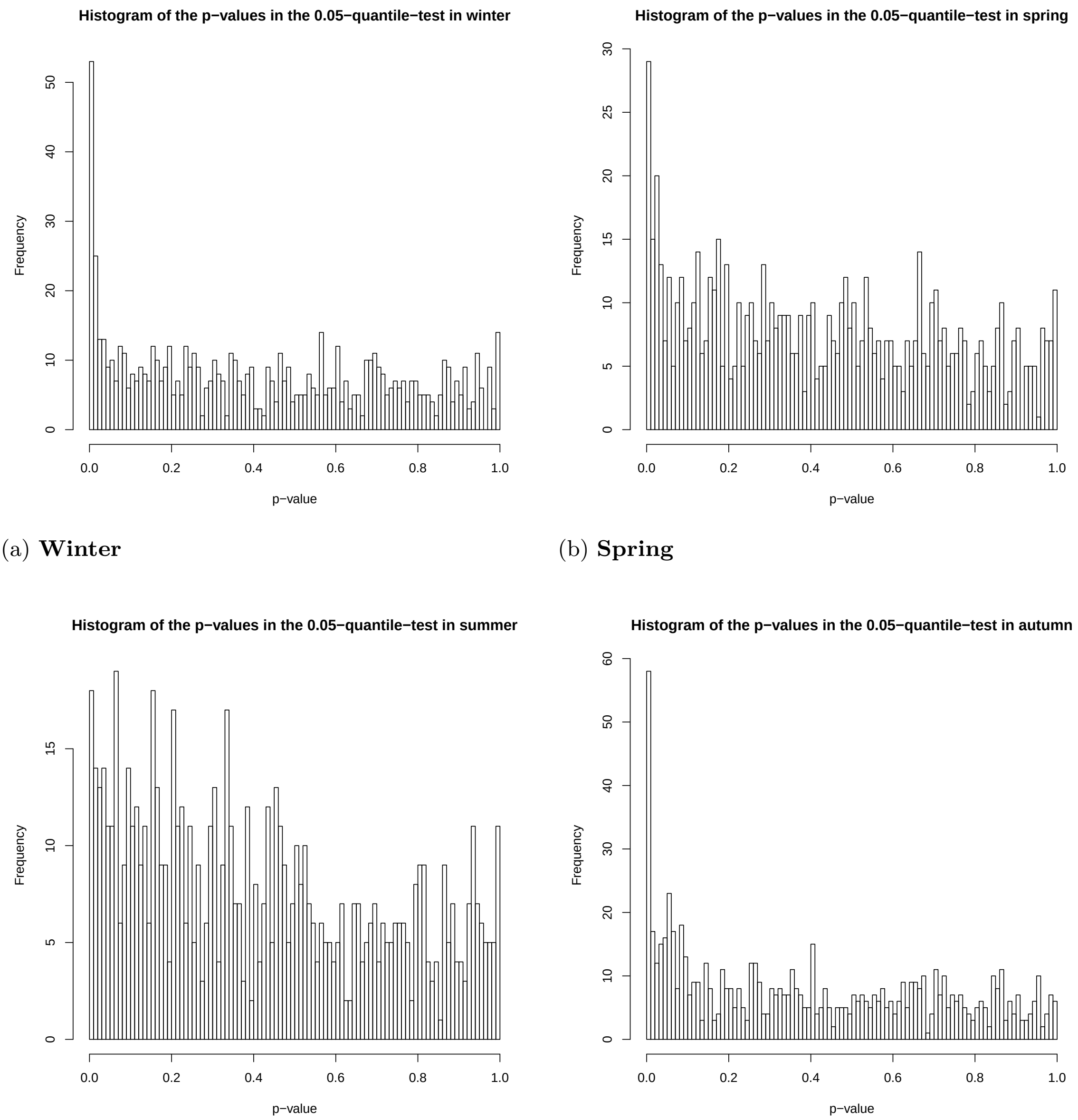


(c) **Summer;**
max blue: OBS 225% $>$ dERA40,
max red: dERA40 96% $>$ OBS.



(d) **Autumn;**
max blue: OBS 352% $>$ dERA40,
max red: dERA40 48% $>$ OBS.

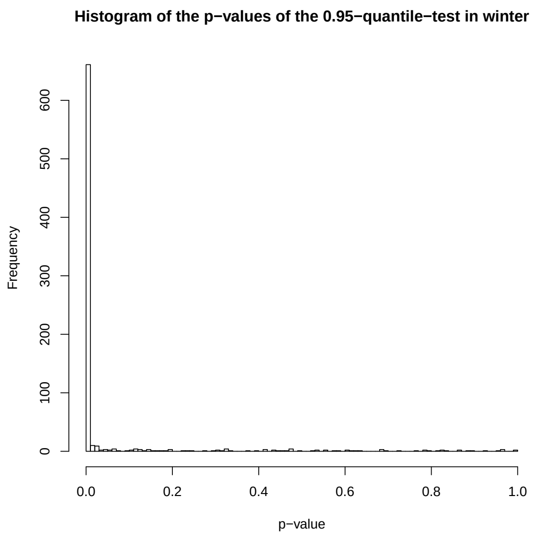
Figure 2. Test of the difference of the standard deviation of the precipitation (conditioned on wet days), $\alpha = 0.05$. When the $p - value > \alpha$, we keep the hypothesis that $sd_{ERA40} = sd_{OBS}$, and this is shown by a yellow color of the grid cell. When $p - value \leq \alpha$ the color of a grid cell is either red or blue, dependent on the direction of the ratio of ERA40/OBS. The darker color of a grid cell, the greater or smaller value of the ratio of ERA40/OBS, as shown in the table. Blue color indicates that $sd_{ERA40} < sd_{OBS}$, significantly, and red color indicates that $sd_{ERA40} > sd_{OBS}$, significantly.



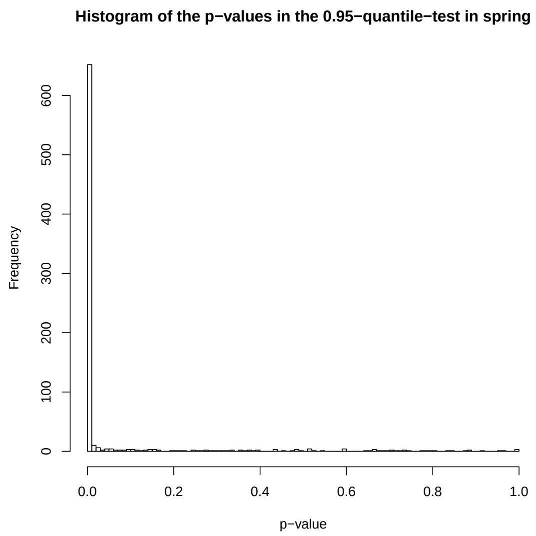
(a) **Winter** (b) **Spring**

(c) **Summer** (d) **Autumn**

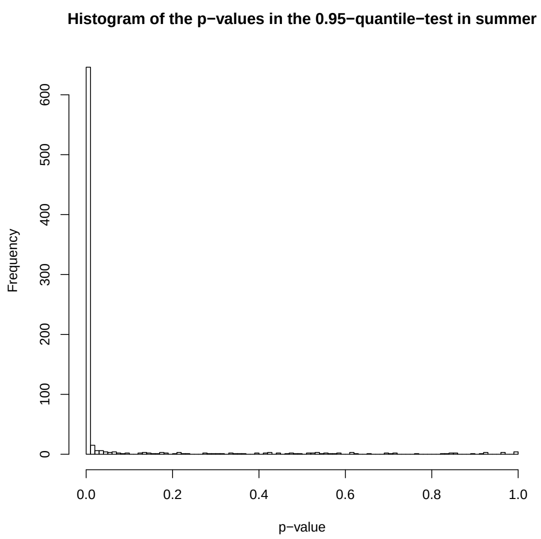
Figure 3. Histogram of the p-values of the test of 0.05-quantiles.



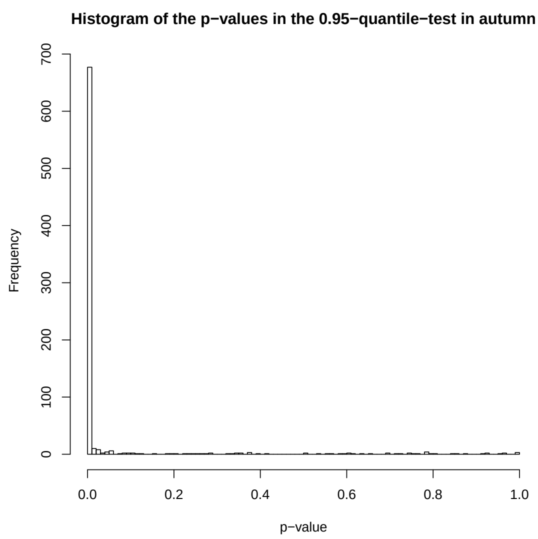
(a) **Winter**



(b) **Spring**

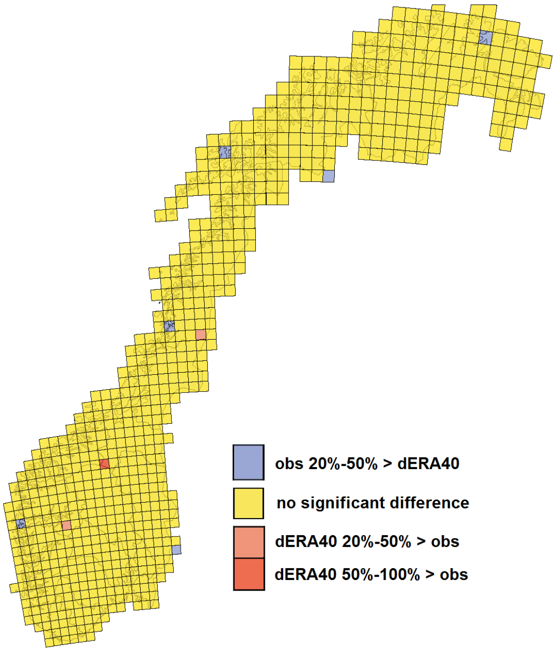


(c) **Summer**

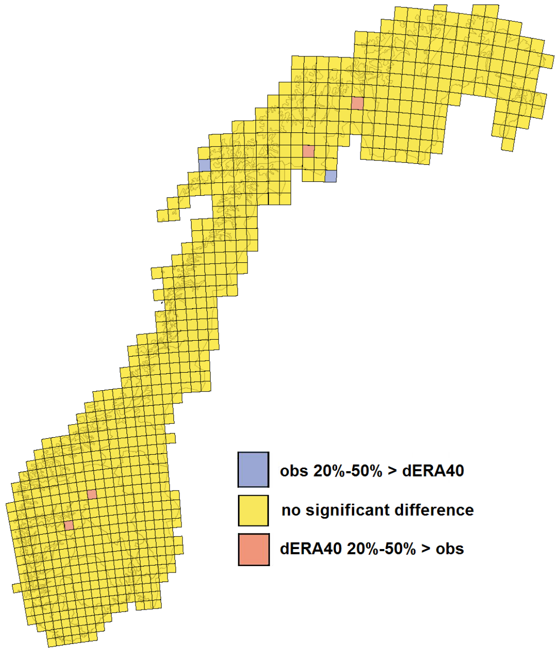


(d) **Autumn**

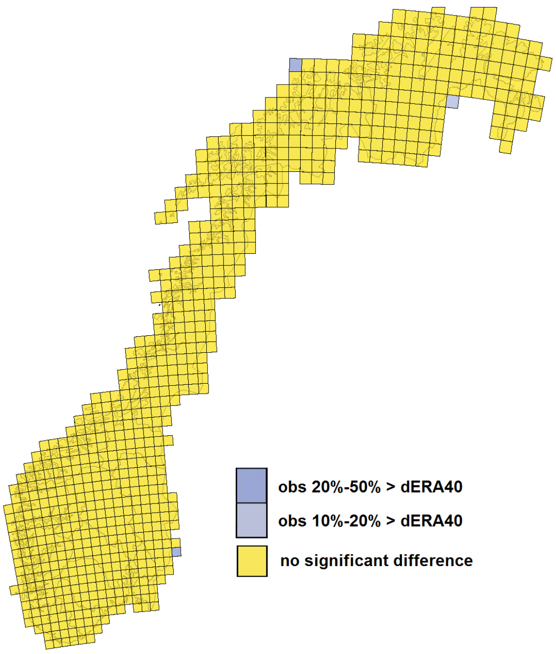
Figure 4. Histogram of the p-values of the test of 0.95-quantiles.



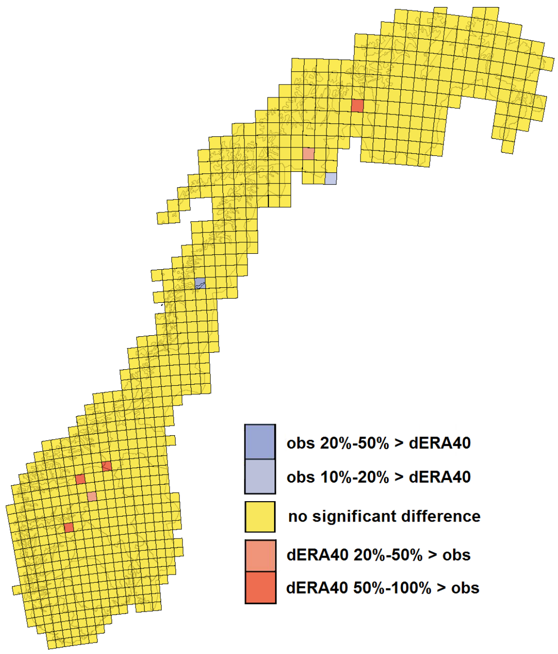
(a) **Winter;**
max blue: OBS 49% > dERA40,
max red: dERA40 53% > OBS.



(b) **Spring;**
max blue: OBS 28% > dERA40,
max red: dERA40 49% > OBS.

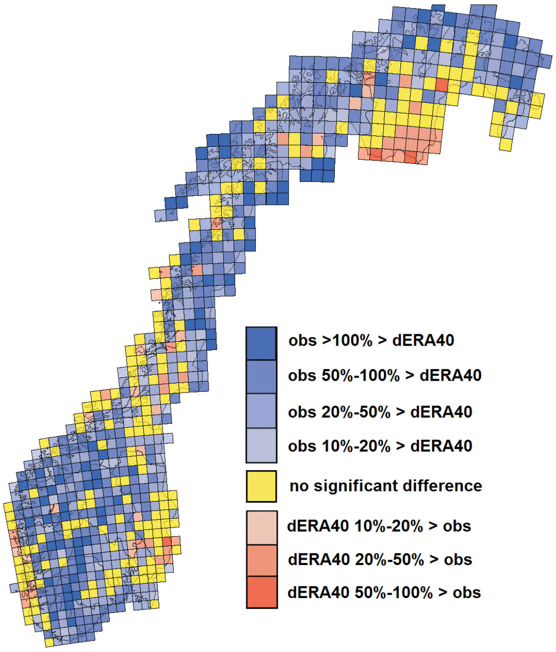


(c) **Summer;**
max blue: OBS 39% > dERA40,
max red: dERA40 30% > OBS.

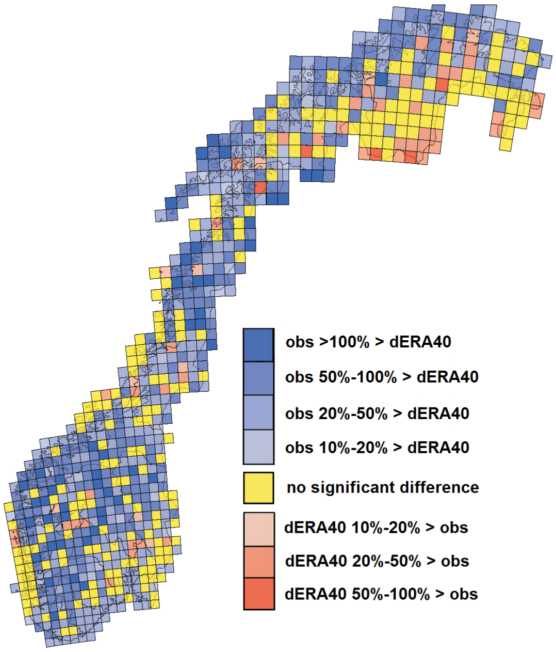


(d) **Autumn;**
max blue: OBS 36% > dERA40,
max red: dERA40 73% > OBS.

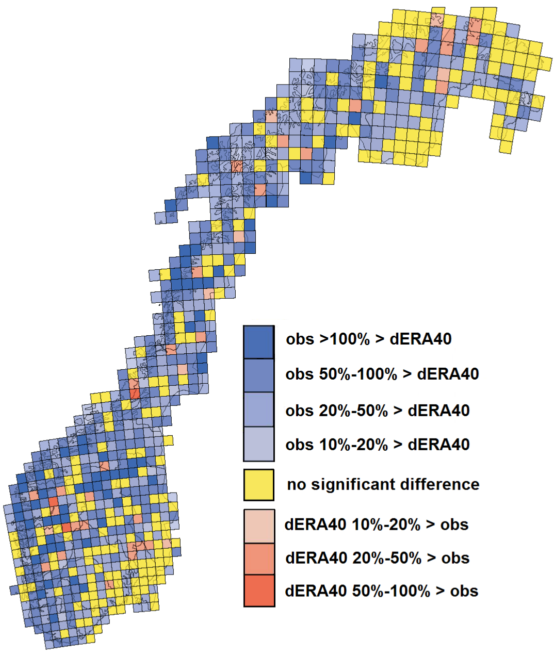
Figure 5. Test of the difference of the 0.05-quantile of the precipitation (conditioned on wet days), $\alpha = 0.05/777$. When the $p - value > \alpha$, we keep the hypothesis that $Q05_{ERA40} = Q05_{OBS}$, and this is shown by a yellow color of the grid cell. When $p - value \leq \alpha$ the color of a grid cell is either red or blue, dependent on the direction of the ratio of ERA40/OBS. The darker color of a grid cell, the greater or smaller value of the ratio of ERA40/OBS, as shown in the table. Blue color indicates that $Q05_{ERA40} < Q05_{OBS}$, significantly, and red color indicates that $Q05_{ERA40} > Q05_{OBS}$, significantly.



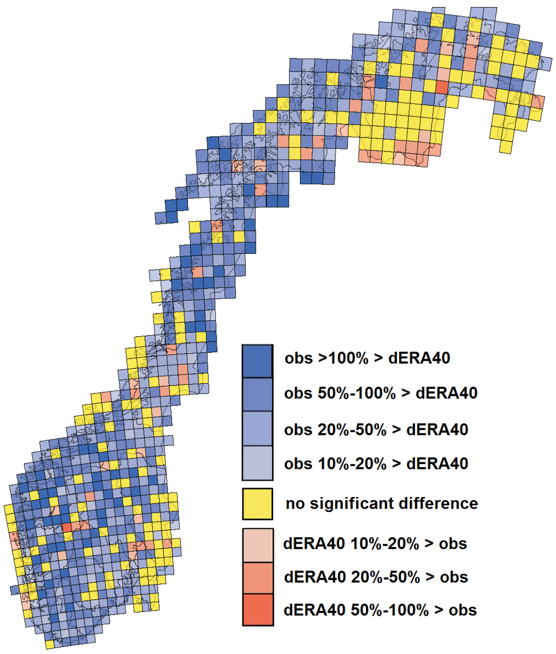
(a) **Winter;**
max blue: OBS 383% > dERA40,
max red: dERA40 80% > OBS.



(b) **Spring;**
max blue: OBS 259% > dERA40,
max red: dERA40 74% > OBS.

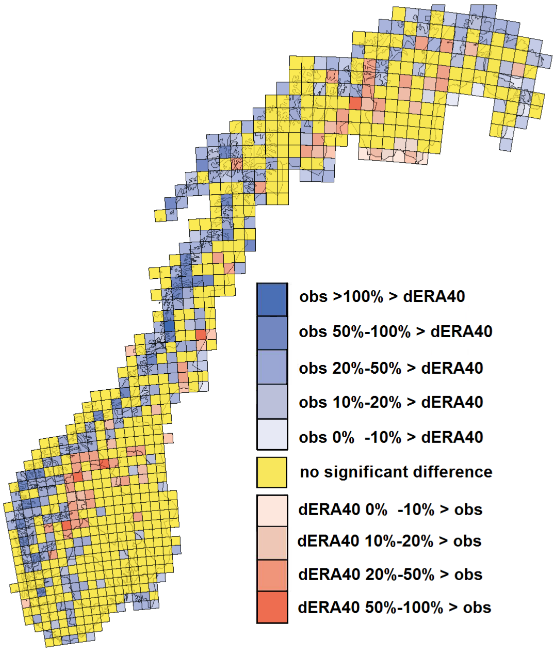


(c) **Summer;**
max blue: OBS 248% > dERA40,
max red: dERA40 93% > OBS.



(d) **Autumn;**
max blue: OBS 312% > dERA40,
max red: dERA40 53% > OBS.

Figure 6. Test of the difference of the 0.95-quantile of the precipitation (conditioned on wet days), $\alpha = 0.05/777$. When the $p - value > \alpha$, we keep the hypothesis that $Q95_{ERA40} = Q95_{OBS}$, and this is shown by a yellow color of the grid cell. When $p - value \leq \alpha$ the color of a grid cell is either red or blue, dependent on the direction of the ratio of ERA40/OBS. The darker color of a grid cell, the greater or smaller value of the ratio of ERA40/OBS, as shown in the table. Blue color indicates that $Q95_{ERA40} < Q95_{OBS}$, significantly, and red color indicates that $Q95_{ERA40} > Q95_{OBS}$, significantly.



(a) **Winter;**
max blue: OBS 104% $>$ dERA40,
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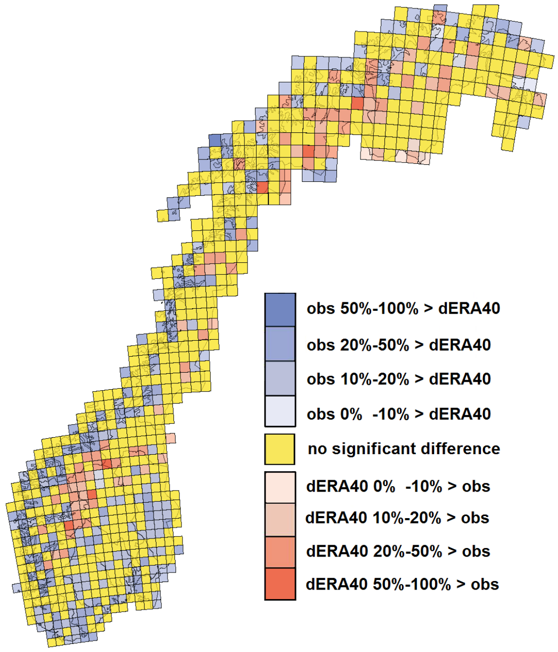
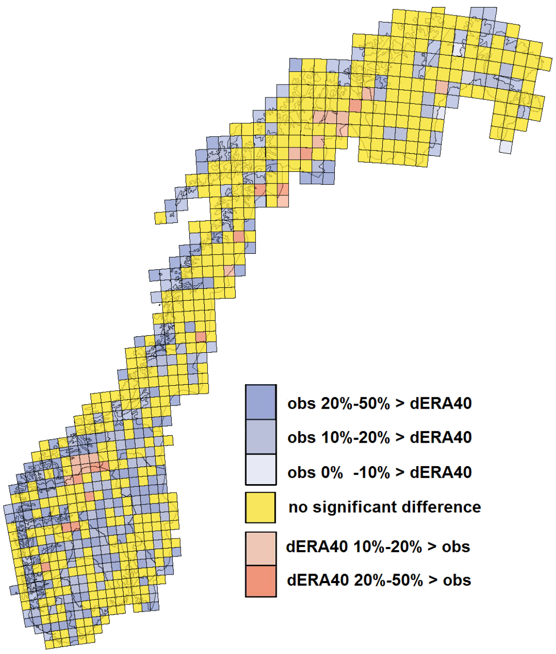


(b) **Spring;**
max blue: OBS 55% $>$ dERA40,
max red: dERA40 80% $>$ OBS.



(c) **Summer;**
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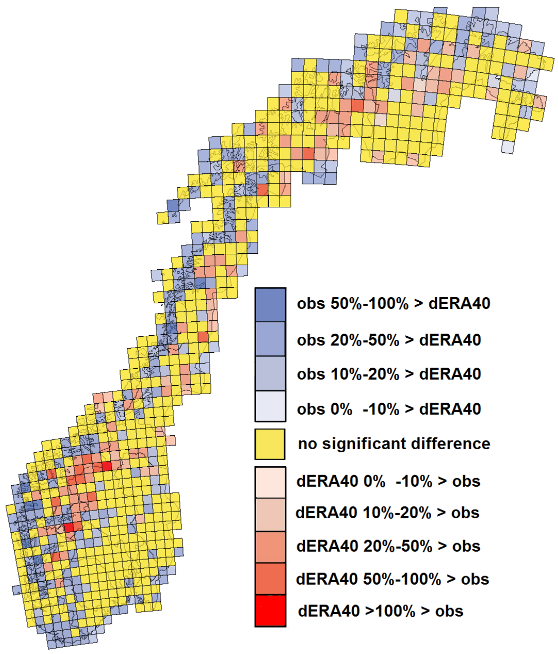
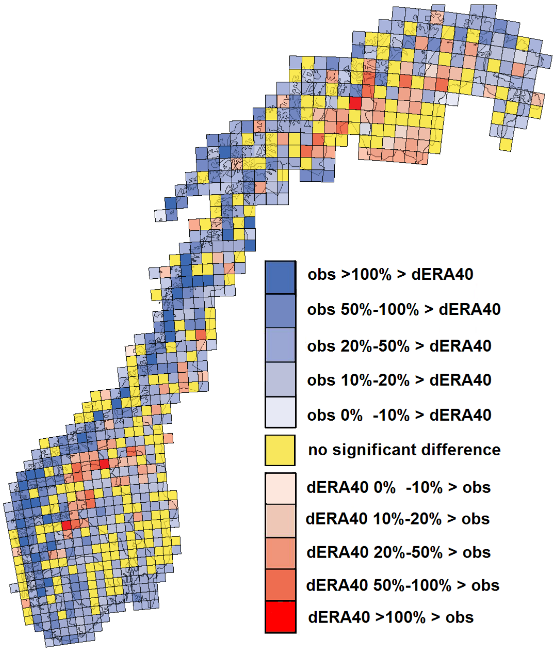
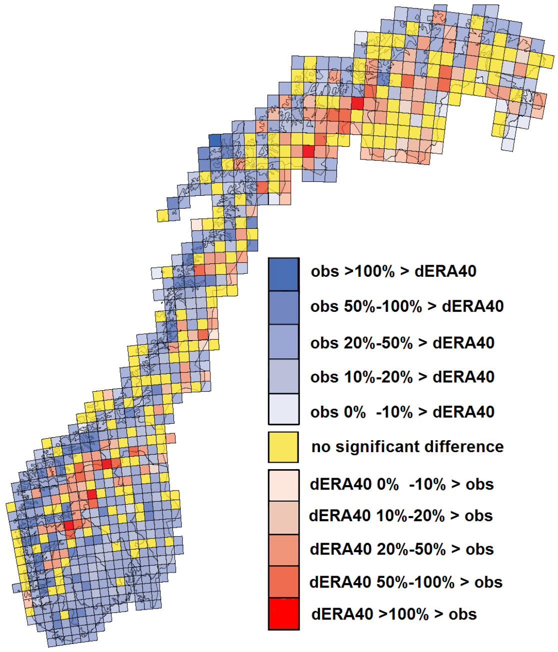


(d) **Autumn;**
max blue: OBS 66% $>$ dERA40,
max red: dERA40 123% $>$ OBS.

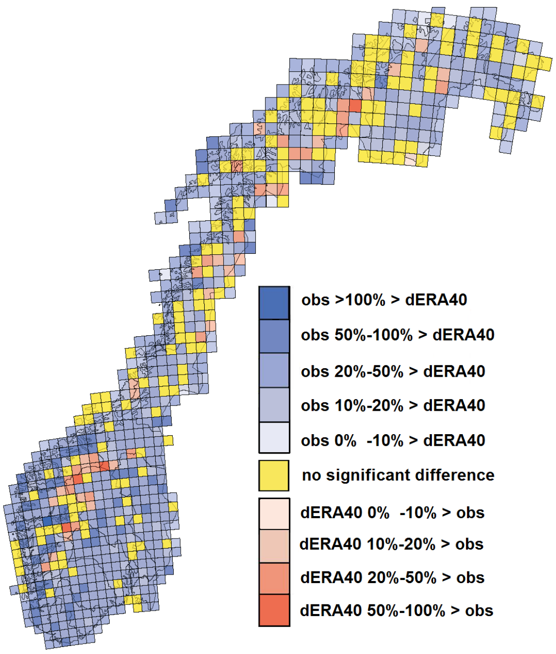
Figure 7. Test of the difference of the 0.10-quantile of the precipitation (conditioned on wet days), $\alpha = 0.05$. When the $p - value > \alpha$, we keep the hypothesis that $Q10_{ERA40} = Q10_{OBS}$, and this is shown by a yellow color of the grid cell. When $p - value \leq \alpha$ the color of a grid cell is either red or blue, dependent on the direction of the ratio of ERA40/OBS. The darker color of a grid cell, the greater or smaller value of the ratio of ERA40/OBS, as shown in the table. Blue color indicates that $Q10_{ERA40} < Q10_{OBS}$, significantly, and red color indicates that $Q10_{ERA40} > Q10_{OBS}$, significantly.



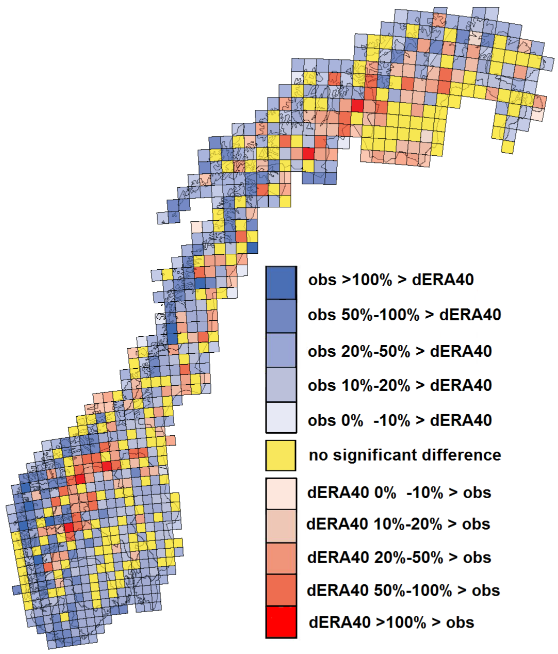
(a) **Winter;**
max blue: OBS 197% > dERA40,
max red: dERA40 129% > OBS.



(b) **Spring;**
max blue: OBS 103% > dERA40,
max red: dERA40 145% > OBS.

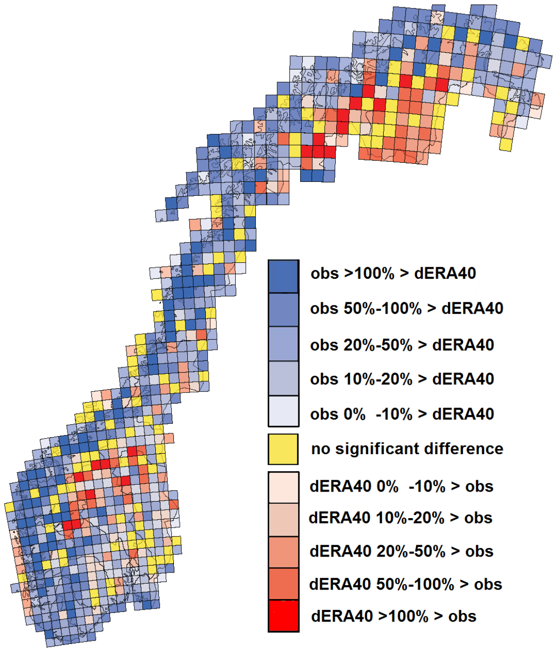


(c) **Summer;**
max blue: OBS 107% > dERA40,
max red: dERA40 79% > OBS.

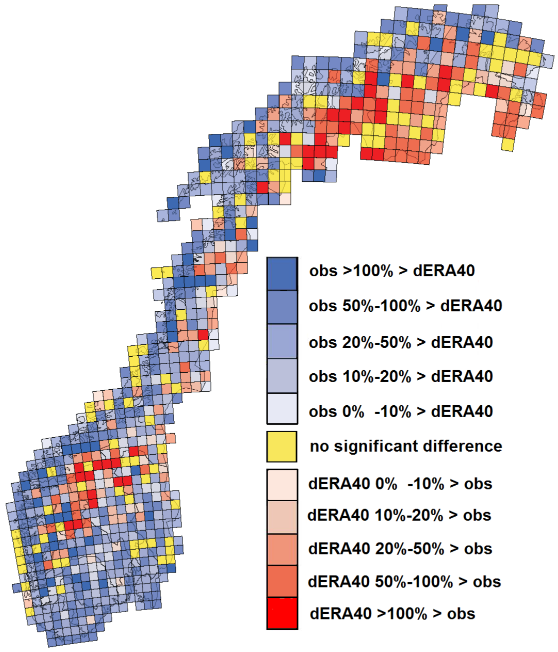


(d) **Autumn;**
max blue: OBS 126% > dERA40,
max red: dERA40 173% > OBS.

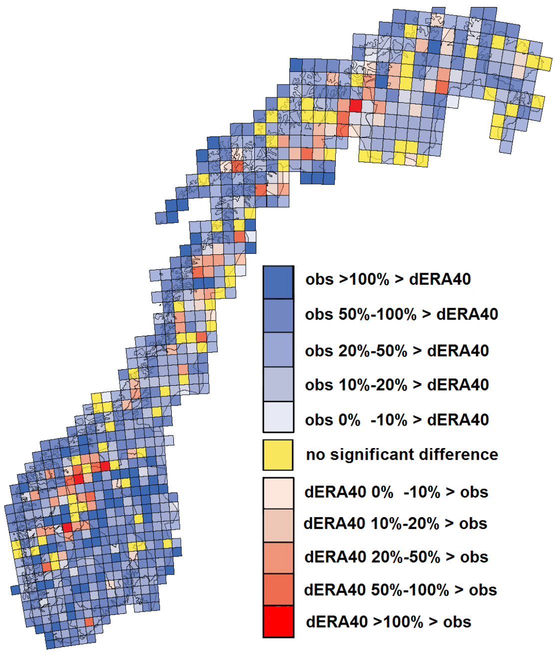
Figure 8. Test of the difference of the 0.25-quantile of the precipitation (conditioned on wet days), $\alpha = 0.05$. When the $p - value > \alpha$, we keep the hypothesis that $Q25_{ERA40} = Q25_{OBS}$, and this is shown by a yellow color of the grid cell. When $p - value \leq \alpha$ the color of a grid cell is either red or blue, dependent on the direction of the ratio of ERA40/OBS. The darker color of a grid cell, the greater or smaller value of the ratio of ERA40/OBS, as shown in the table. Blue color indicates that $Q25_{ERA40} < Q25_{OBS}$, significantly, and red color indicates that $Q25_{ERA40} > Q25_{OBS}$, significantly.



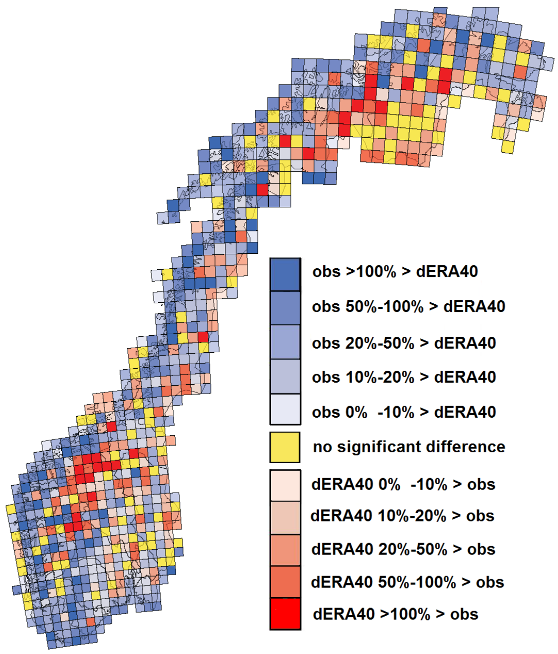
(a) **Winter;**
max blue: OBS 276% > dERA40,
max red: dERA40 282% > OBS.



(b) **Spring;**
max blue: OBS 224% > dERA40,
max red: dERA40 407% > OBS.

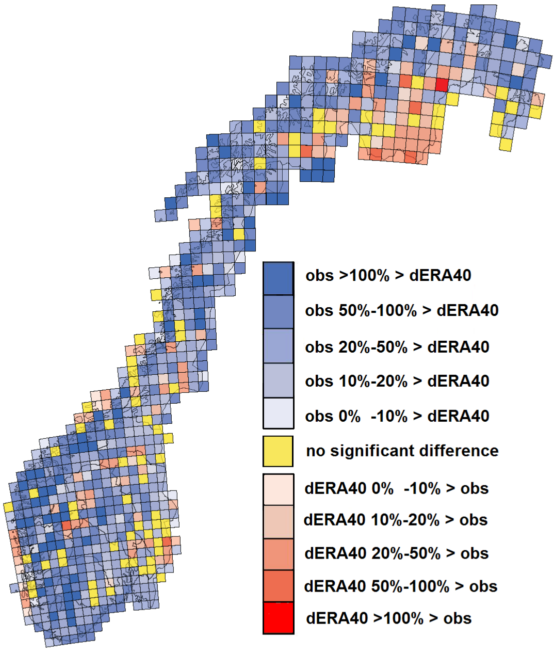


(c) **Summer;**
max blue: OBS 255% > dERA40,
max red: dERA40 162% > OBS.

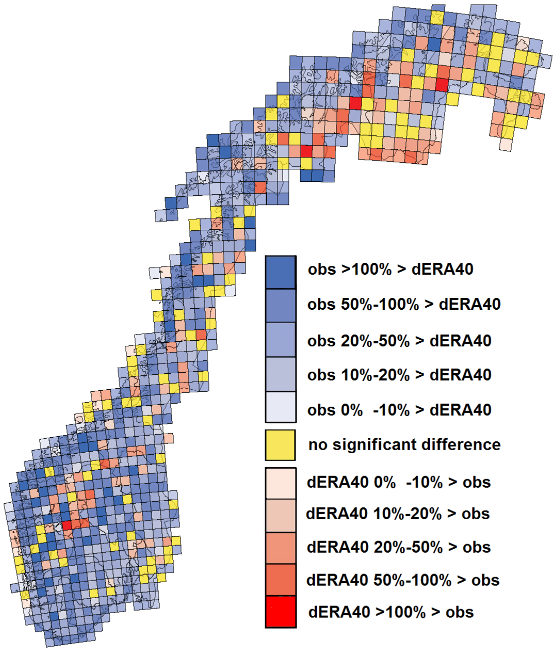


(d) **Autumn;**
max blue: OBS 235% > dERA40,
max red: dERA40 330% > OBS.

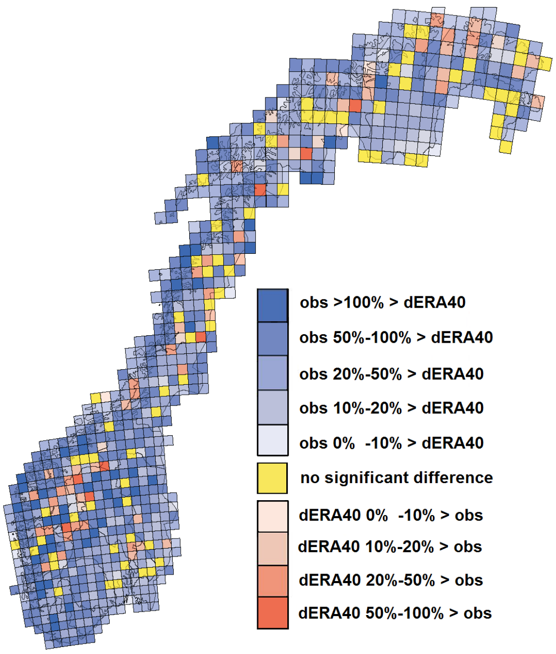
Figure 9. Test of the difference of the median of the precipitation (conditioned on wet days), $\alpha = 0.05$. When the $p - value > \alpha$, we keep the hypothesis that $Q50_{ERA40} = Q50_{OBS}$, and this is shown by a yellow color of the grid cell. When $p - value \leq \alpha$ the color of a grid cell is either red or blue, dependent on the direction of the ratio of ERA40/OBS. The darker color of a grid cell, the greater or smaller value of the ratio of ERA40/OBS, as shown in the table. Blue color indicates that $Q50_{ERA40} < Q50_{OBS}$, significantly, and red color indicates that $Q50_{ERA40} > Q50_{OBS}$, significantly.



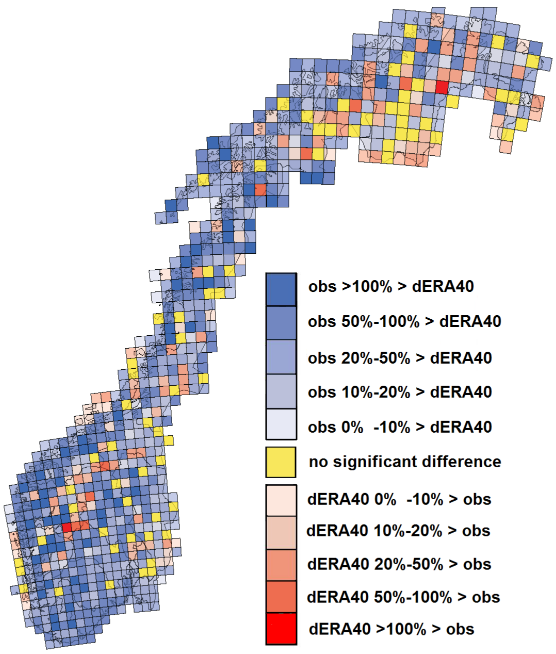
(a) **Winter;**
max blue: OBS 314% > dERA40,
max red: dERA40 106% > OBS.



(b) **Spring;**
max blue: OBS 209% > dERA40,
max red: dERA40 143% > OBS.

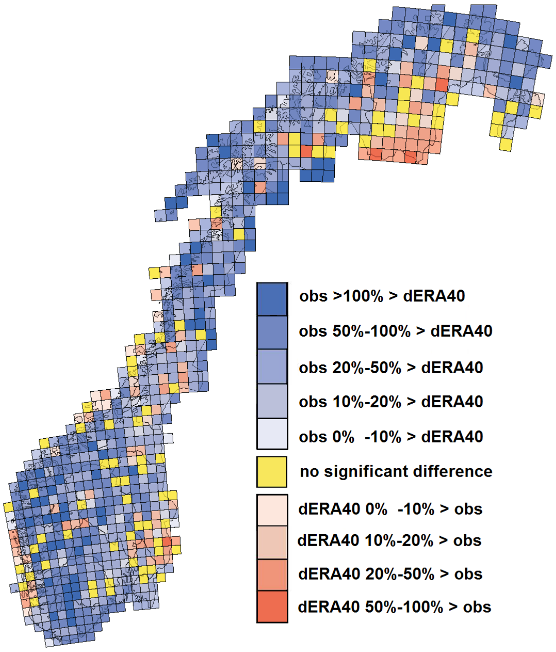


(c) **Summer;**
max blue: OBS 232% > dERA40,
max red: dERA40 95% > OBS.

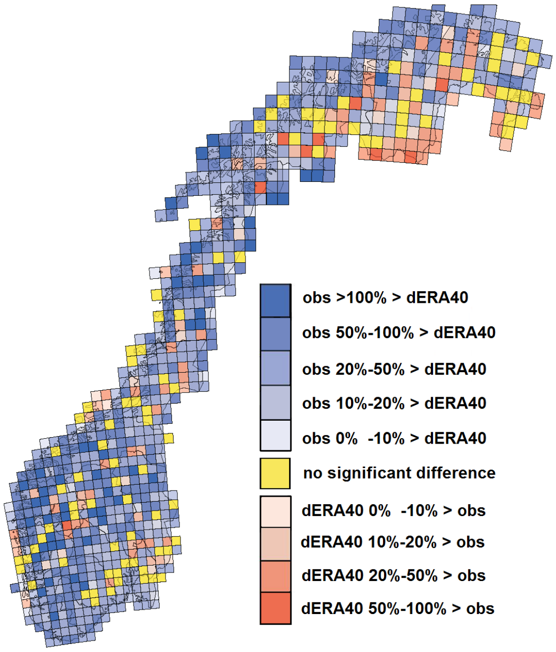


(d) **Autumn;**
max blue: OBS 245% > dERA40,
max red: dERA40 102% > OBS.

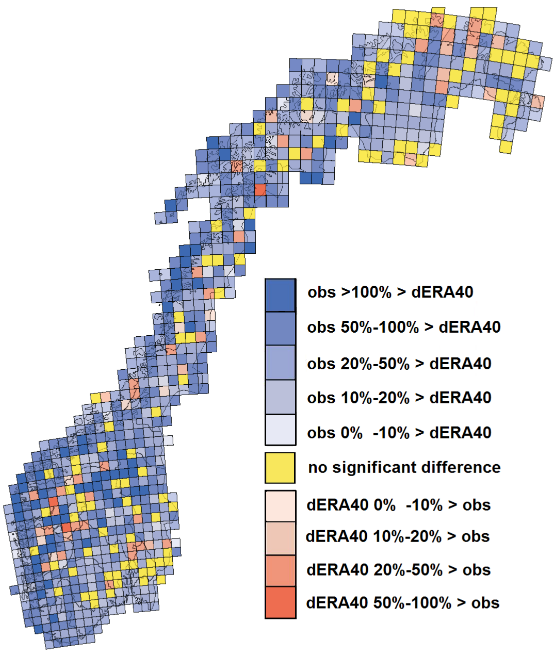
Figure 10. Test of the difference of the 0.75-quantile of the precipitation (conditioned on wet days), $\alpha = 0.05$. When the $p - value > \alpha$, we keep the hypothesis that $Q75_{ERA40} = Q75_{OBS}$, and this is shown by a yellow color of the grid cell. When $p - value \leq \alpha$ the color of a grid cell is either red or blue, dependent on the direction of the ratio of ERA40/OBS. The darker color of a grid cell, the greater or smaller value of the ratio of ERA40/OBS, as shown in the table. Blue color indicates that $Q75_{ERA40} < Q75_{OBS}$, significantly, and red color indicates that $Q75_{ERA40} > Q75_{OBS}$, significantly.



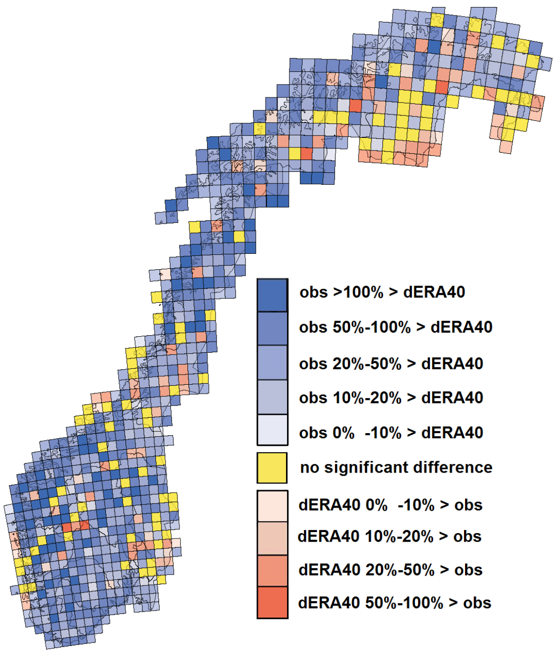
(a) **Winter;**
max blue: OBS 384% > dERA40,
max red: dERA40 84% > OBS.



(b) **Spring;**
max blue: OBS 251% > dERA40,
max red: dERA40 89% > OBS.

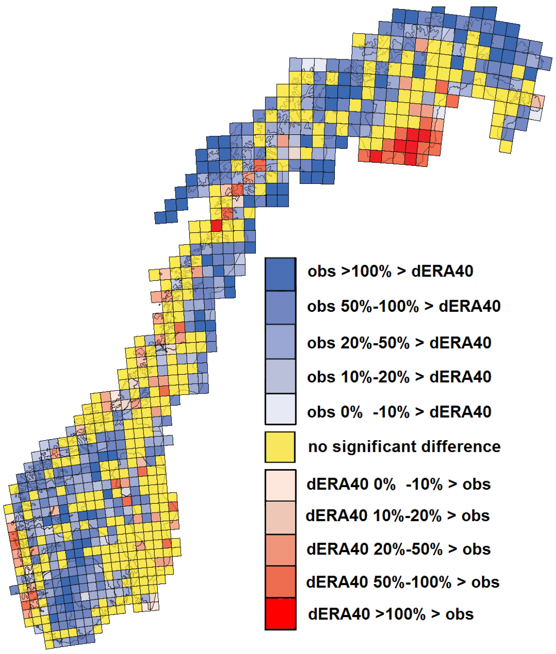


(c) **Summer;**
max blue: OBS 241% > dERA40,
max red: dERA40 90% > OBS.

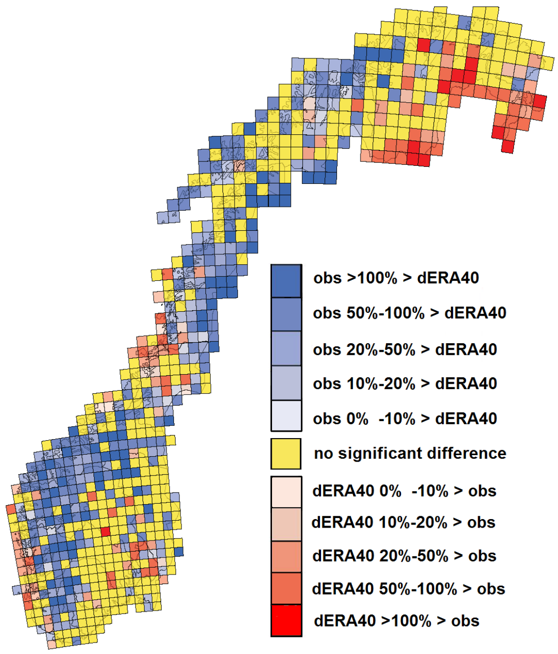


(d) **Autumn;**
max blue: OBS 280% > dERA40,
max red: dERA40 72% > OBS.

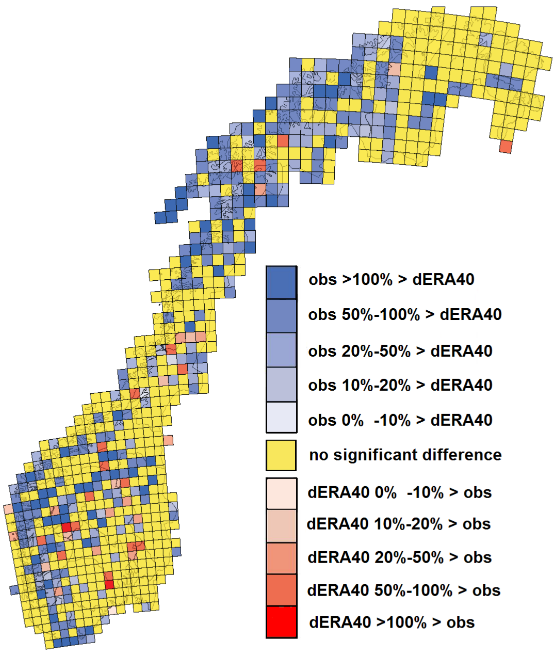
Figure 11. Test of the difference of the 0.90-quantile of the precipitation (conditioned on wet days), $\alpha = 0.05$. When the $p - value > \alpha$, we keep the hypothesis that $Q90_{ERA40} = Q90_{OBS}$, and this is shown by a yellow color of the grid cell. When $p - value \leq \alpha$ the color of a grid cell is either red or blue, dependent on the direction of the ratio of ERA40/OBS. The darker color of a grid cell, the greater or smaller value of the ratio of ERA40/OBS, as shown in the table. Blue color indicates that $Q90_{ERA40} < Q90_{OBS}$, significantly, and red color indicates that $Q90_{ERA40} > Q90_{OBS}$, significantly.



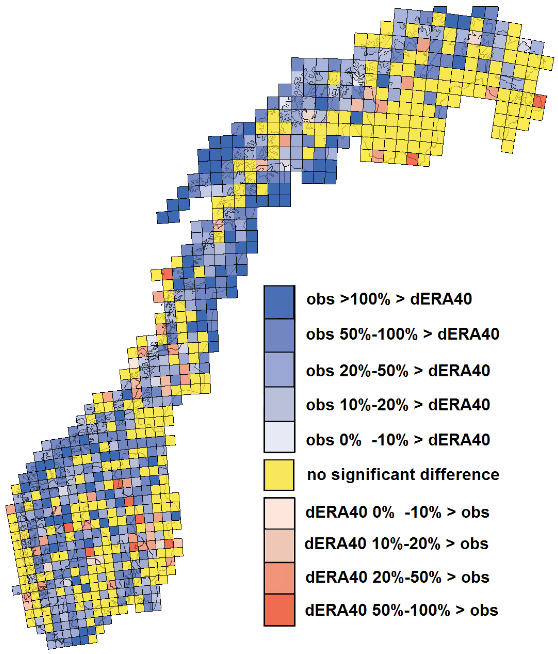
(a) **Winter;**
max blue: OBS 632% > dERA40,
max red: dERA40 135% > OBS.



(b) **Spring;**
max blue: OBS 440% > dERA40,
max red: dERA40 202% > OBS.

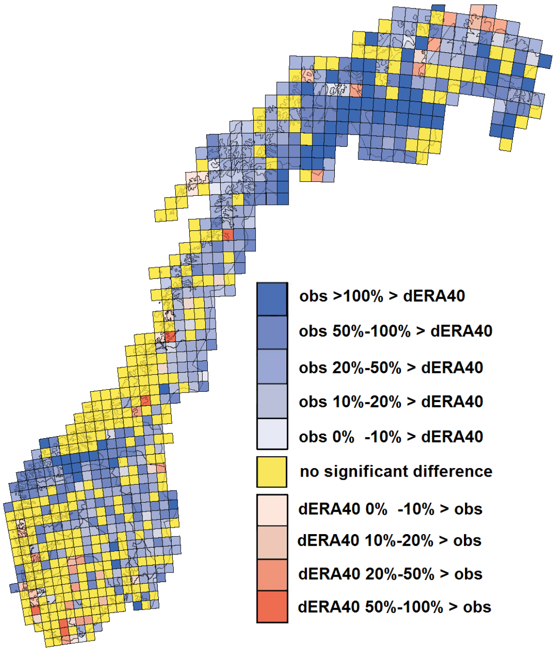


(c) **Summer;**
max blue: OBS 234% > dERA40,
max red: dERA40 110% > OBS.

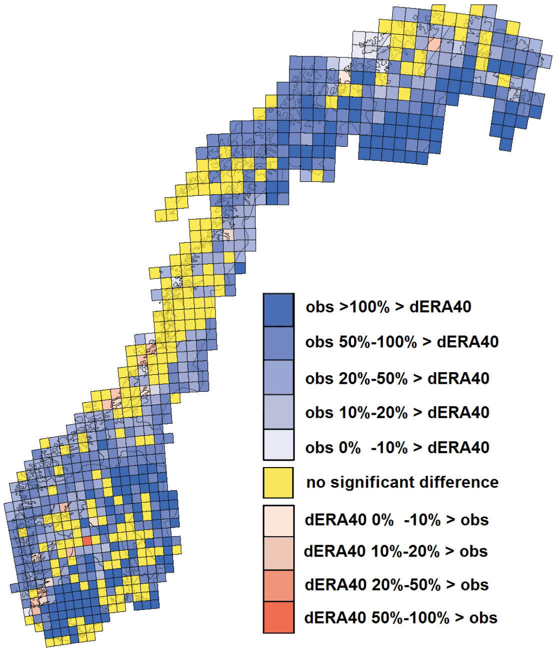


(d) **Autumn;**
max blue: OBS 435% > dERA40,
max red: dERA40 95% > OBS.

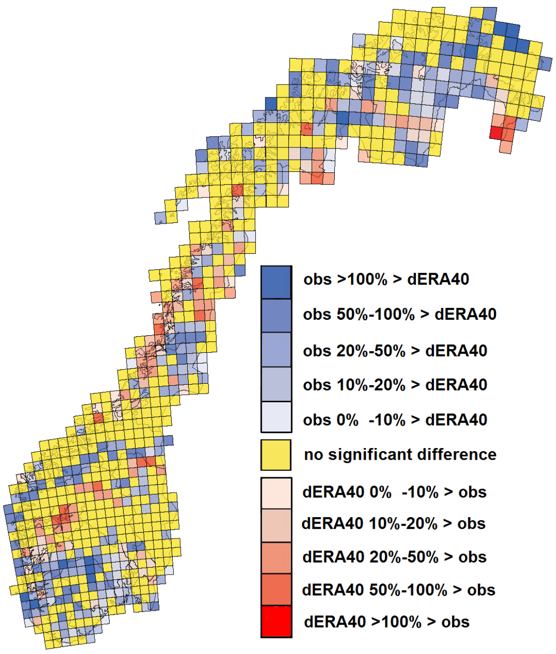
Figure 12. Test of the difference of the maximum 5-day precipitation, $\alpha = 0.05$. When the $p{-}value > \alpha$, we keep the hypothesis that $MAX5_{ERA40} = MAX5_{OBS}$, and this is shown by a yellow color of the grid cell. When $p - value \leq \alpha$ the color of a grid cell is either red or blue, dependent on the direction of the ratio of ERA40/OBS. Blue color indicates that $MAX5_{ERA40} < MAX5_{OBS}$, significantly, and red color indicates that $MAX5_{ERA40} > MAX5_{OBS}$, significantly.



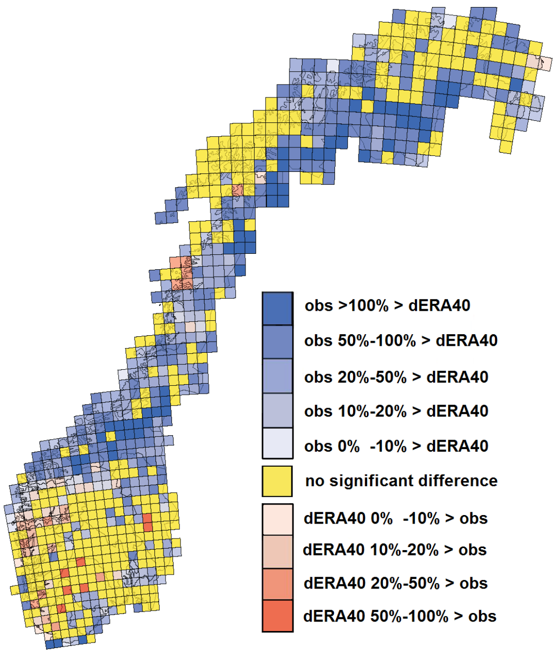
(a) **Winter;**
max blue: OBS 300% > dERA40,
max red: dERA40 84% > OBS.



(b) **Spring;**
max blue: OBS 291% > dERA40,
max red: dERA40 63% > OBS.



(c) **Summer;**
max blue: OBS 192% > dERA40,
max red: dERA40 118% > OBS.



(d) **Autumn;**
max blue: OBS 225% > dERA40,
max red: dERA40 73% > OBS.

Figure 13. Test of the difference of the maximum number of consecutive dry days, $\alpha = 0.05$. When the $p - value > \alpha$, we keep the hypothesis that $MAXDRY_{ERA40} = MAXDRY_{OBS}$, and this is shown by a yellow color of the grid cell. When $p - value \leq \alpha$ the color of a grid cell is either red or blue, dependent on the direction of the ratio of ERA40/OBS. The darker color of a grid cell, the greater or smaller value of the ratio of ERA40/OBS, as shown in the table. Blue color indicates that $MAXDRY_{ERA40} < MAXDRY_{OBS}$, significantly, and red color indicates that $MAXDRY_{ERA40} > MAXDRY_{OBS}$, significantly.

4 Linear adjustment

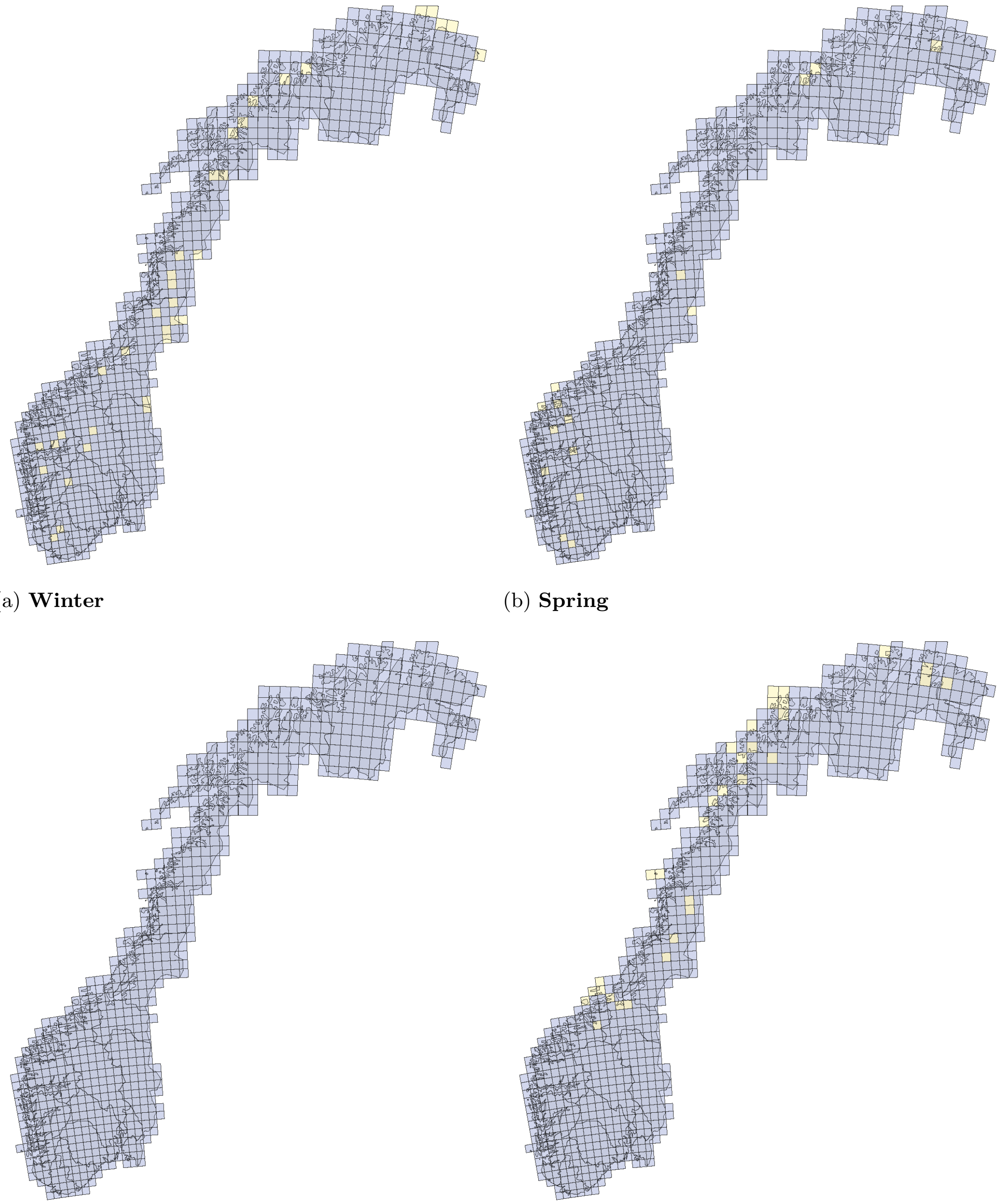
4.1 Kolmogorov Smirnov 2 sample test

Transforming dERA40 by a simple linear regression does not improve dERA40 as we see from the Kolmogorv Smirnov test in Figure 14. Note that the KS-test for the summer actually is worse after transforming dERA40, i.e. there are less non-rejections. The mean of the parameters a is about twice as big for the summer than the other seasons[2]. This might affect the data so that there are too many rainy days compared to the observations. Note that the KS-test is tested on the data set conditioned on wet days, but the transformation is done on the whole data set (both wet and dry days).

This picture shows that a simple linear regression does not work. A more complex transformation is necessary.

The same transformation is also performed on wet days only, but this did neither improve dERA40. For all seasons, except summer, the KS-test actually resulted in less non-rejections. The picture of the KS-test of this transformation is not shown.

2. a is about 4 in mean



(a) **Winter** (b) **Spring** (c) **Summer** (d) **Autumn**

Figure 14. Kolmogorov Smirnov 2 sample test is used with $\alpha = 0.05$. A grid cell is yellow if the $p - value > \alpha$. If the $p - value \leq \alpha$ the grid cell is blue.

References

Bickel, P. J. and Doksum, K. A. (1977). *Mathematical Statistics: Basic ideas and selected topics.* Holden-Day.

Good, P. I. (2005). *Permutation, Parametric and Bootstrap Tests of Hypotheses*. Springer.

Appendix

A Comparative methods to the Kolmogorov-Smirnov test

Typically, in situations with lots of data, even small differences come out statistically significant. Hence the Kolmogorov-Smirnov test easily returns rejection of the null hypothesis. To illustrate how different the distributions of dERA40 and OBS are with other tools than Kolmogorov-Smirnov, empirical density functions and empirical cumulative distribution functions of four grid cells (for one season) are shown in Figures A-1 and A-2.

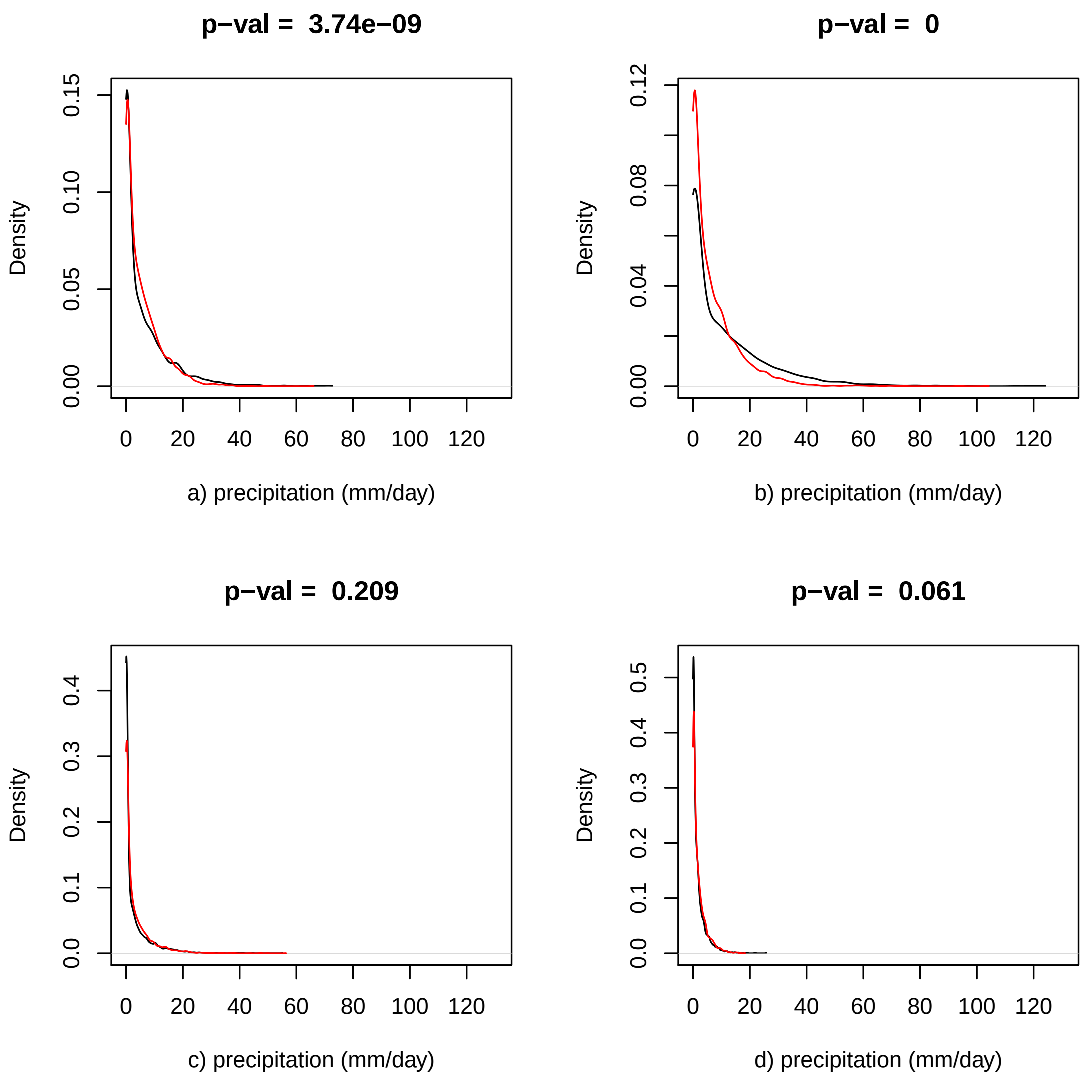


Figure A-1. Density distribution function for four different grid cells.

The subfigures a (and b, c and d) in Figures A-1 and A-2 correspond to the same grid cells/data sets. The p-value from the Kolmogorov-Smirnov test is shown above each subfigure. Two grid cells with rejections (subfigures a and b) and two with non-rejections (subfigures c and d) are picked for illustration. From the empirical distribution functions and density functions it is clear that the distributions of dERA40 and OBS in subfigures c and d are more similar than the distributions in subfigures a and b. But even though Kolmogorov-Smirnov reject the null hypothesis of equality of the distributions in subfigures a, the distribution of dERA40 is not that far away from the distribution of OBS, at least for low quantiles. When considering the extremes it is difficult to deduse something just from this illustration. The distributions in subfigures b seem more distinct than the distributions in subfigures a from the empirical cumulative functions and empirical density function, as is also in accordance with the Kolmogorov-Smirnov test.

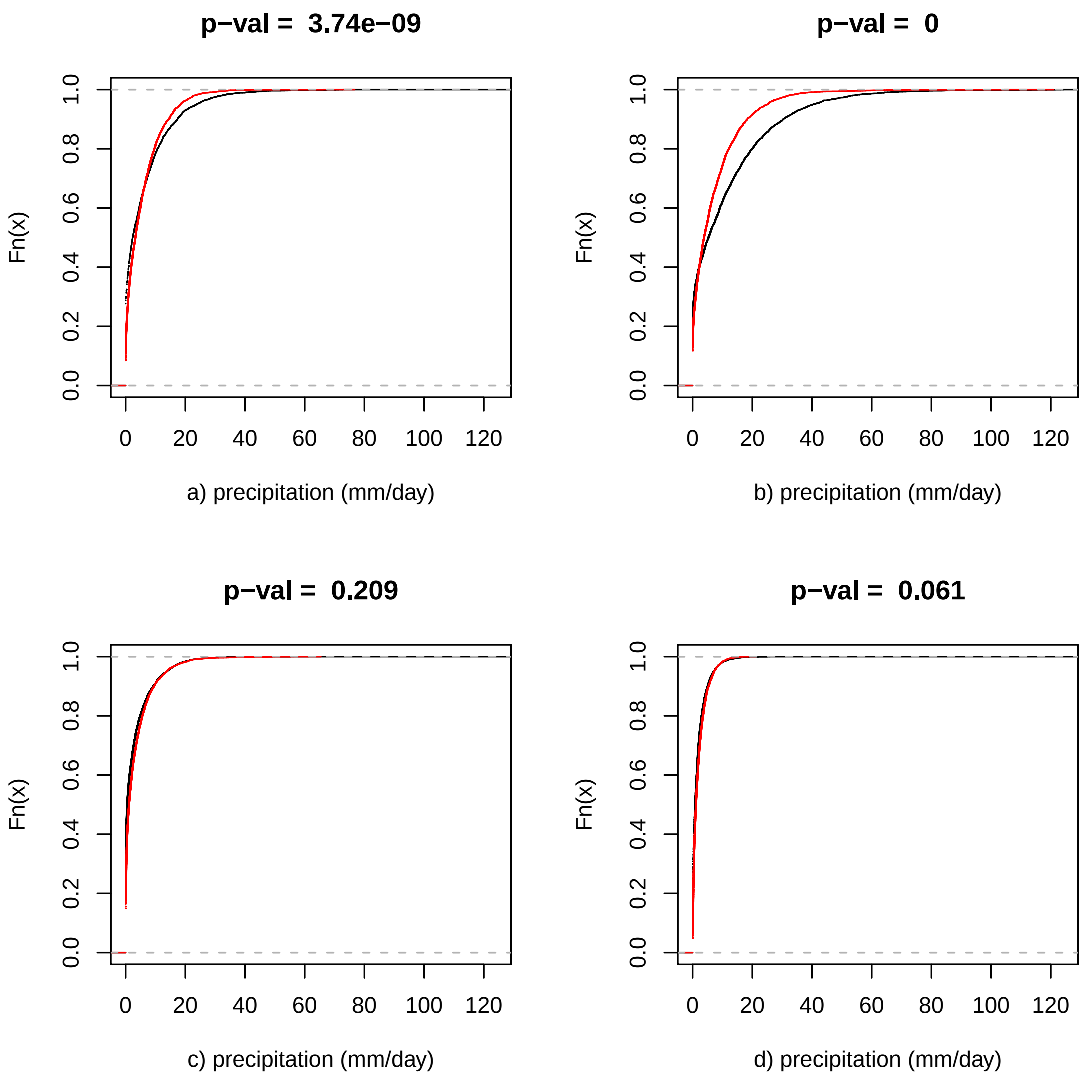


Figure A-2. Empirical cumulative distribution function for four different grid cells.